NUMERICAL SIMULATIONS OF ROCK MECHANICS LABORATORY TESTS ON TENNESSEE MARBLE: AXISYMMETRIC AND PLANE STRAIN FORMULATIONS

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We present results of finite element simulations using a non-associated elastoplastic constitutive model for Tennessee marble developed from a suite of axisymmetric compression tests. The constitutive model includes dependence of the dilation factor, friction factor, and plastic hardening modulus on mean stress and accumulated inelastic shear strain. Although the development of the constitutive model assumed uniform deformation in the samples, here we use the numerical simulations to study the evolution of stress and strain inhomogeneities arising from realistic boundary conditions that simulate those in laboratory experiments. Our numerical models involve three distinct configurations for axisymmetric and plane strain experimental setups. The first case is for homogeneous deformation in the marble (corresponding to a vanishing coefficient of friction (COF) at the sample-platen interface). The second case is for a perfectly bonded interface between rock and platen (i.e. no slip between marble and metal). The third case models a frictional interface between the platen and marble, with several different coefficients of friction.

For the axisymmetric cases, the whole-sample nominal stress and strain curves are not greatly affected by different amounts of friction at the sample-platen interface, for all strains attained in the non-homogenous cases. However, we find an interesting variety of mechanical responses within the samples for all non-homogeneous cases, which appear to be due primarily to mean stress variations. For example, non-zero friction at the interface results in hardening at the sample center and near its upper outside edge. At the center, the hardening occurs at a negative plastic hardening modulus while hardening at the outer edge occurs at a positive hardening modulus. Near the outside surface along the middle of the sample, and also near the top centerline, the mean stress increases and then decreases as loading progresses. The decrease at the outside middle area results from deformation into the softening regime; the top center mean stress decrease occurs via elastic unloading from a previously plastic state.

The plane strain samples do not show the variety of responses that are evident in the axisymmetric test pieces, and show only strain hardening and no areas of softening or elastic unloading. The simulations with different COF have whole-sample axial nominal stress versus strain curves that are coincident until late in the loading program. Then, in the vicinity of localization these curves separate slightly from each other and the onset of localization (according to the Rudnicki-Rice Theory of shear band onset [1]) occurs at different stress and strain values. Specifically, the stress and strain at localization onset decrease with increasing COF from the values for the frictionless interface, with localization becoming increasingly likely in the sample center, as opposed to the corners. Our results demonstrate that modest variations in sample-platen friction do not significantly alter the whole-sample stress-strain curves but they can affect the onset and location of localization.

References

[1] Rudnicki, J.W. and Rice, J.R., Conditions for the localization of deformation in pressure-sensitive dilatant materials, *J. Mech. Phys. Solids,* v. 23, p. 371-394, 1975.